MULTIMEDIA UNIVERSITY

STUDENT ID NO

MULTIMEDIA UNIVERSITY

SUPPLEMENTARY EXAMINATION

TRIMESTER 1, 2015/2016

EEE 3076 – POWER ELECTRONICS

(LE, EE, CE, NE)

17 NOV 2015
2.30 PM – 4.30 PM
(2 HOURS)

INSTRUCTIONS TO STUDENTS

1. This Question paper consists of 9 pages including cover page with 4 Questions only.
2. Answer ALL questions. All questions carry equal marks and the distributions of the marks for each question is given.
3. Please print all your answers in the Answer Booklet provided.

Question 1

a) Base driver circuit is used to increase the switching speed of the bipolar junction transistor (BJT). Using a suitable figure, discuss how this circuit can improve the switching speed.

[4 marks]

b) A metal oxide semiconductor field effect transistor (MOSFET) is used as a switch in a DC-DC converter connected to a load. The switching characteristic of the MOSFET is shown in Figure Q1 (a). During OFF-state, V_{DS} = 50 V and I_D = 2.5 mA. During ON-state, V_{DS} = 2 V, I_D = 1 A. Calculate the following:

(i) Static loss

[7 marks]

(ii) Dynamic loss

[6 marks]

(iii) Total loss

[2 marks]

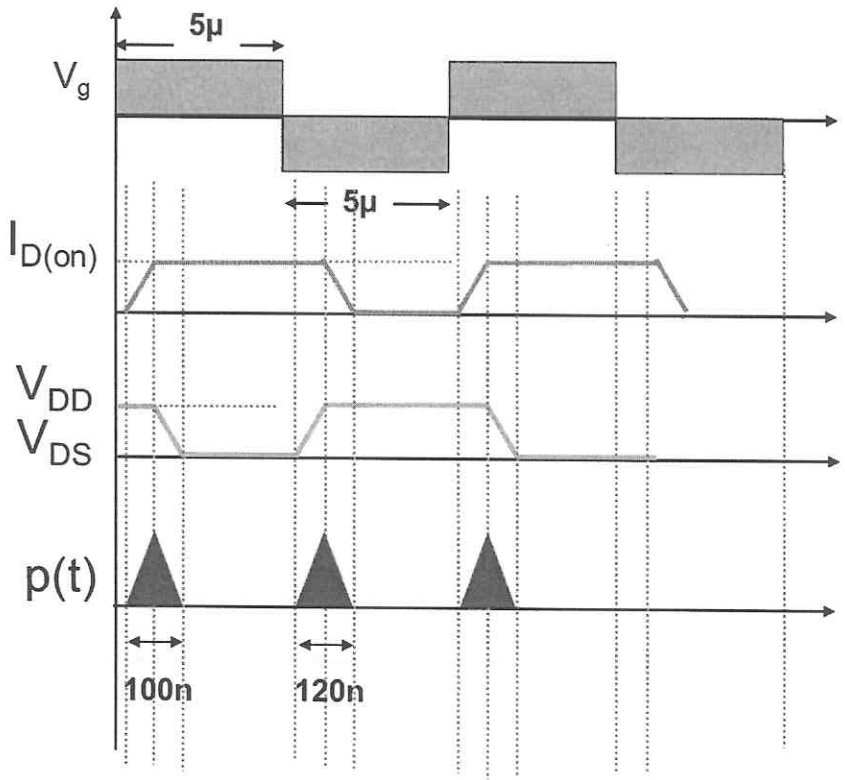

Figure Q1 (a)

Continued...

c) Figure Q1 (b) shows the reverse recovery characteristic of a power diode. If $t_4 = 2\ \mu s$, $t_5 = 2\ \mu s$ and $^{di_R}/_{dt} = 30A/\mu s$, determine t_{rr}, I_{rr} and Q_{rr}.

[6 marks]

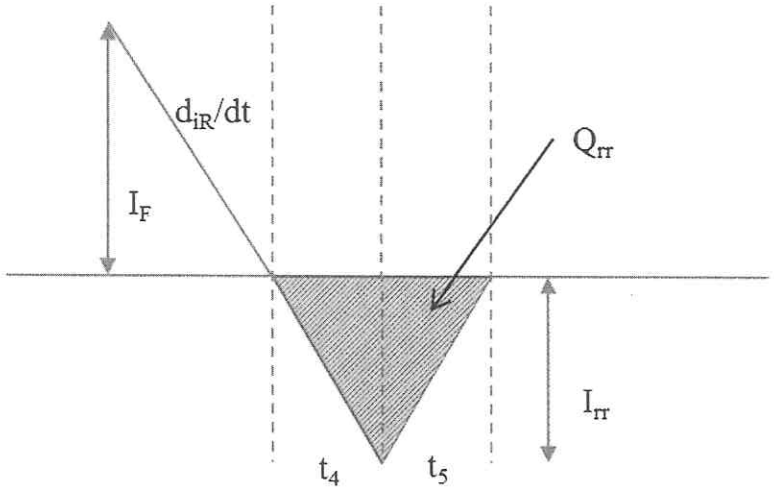

Figure Q1 (b)

Continued...

Question 2

A circuit shown in Figure Q2 is used to supply DC voltage to an R-L Load. The rectifier circuit is expected to yield maximum rectification efficiency.

a) Sketch the circuit diagram of the rectifier.

[2 marks]

b) Sketch the input voltage, output voltage, input and output currents. [Use the sheet in the appendix for sketching.]

[7 marks]

c) Compute the average output voltage (V_O) and current (I_O).

[4 marks]

d) Compute the r.m.s and average values of current at one of the diodes.

[6 marks]

e) State the maximum blocking voltage and forward current of the diode.

[3 marks]

f) Calculate the r.m.s. value of the input current, I_S.

[3 marks]

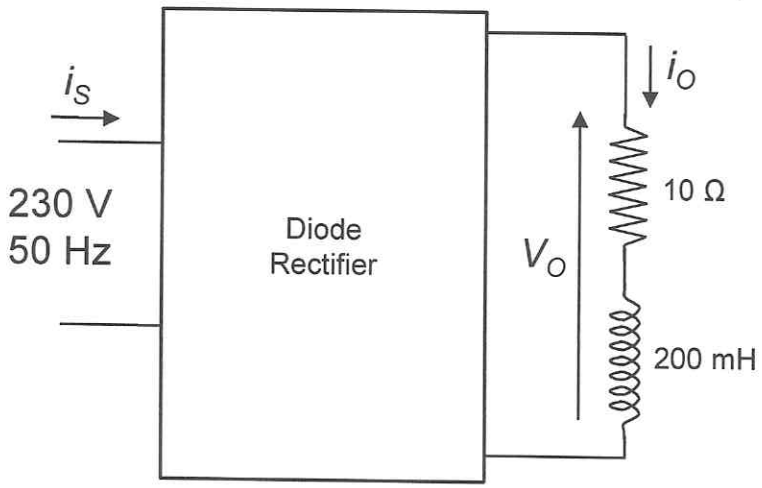

Figure Q2

Continued...

Question 3

(a) Design a boost converter that can generate an output voltage of 50 V from an input voltage of 15 V with a ripple of less than 2% in the output voltage across a load of 25 Ω. This converter should be designed for continuous current operation at a switching frequency f_S = 20 kHz. Determine the voltage rating of the inductor and capacitor. Assume all the components are ideal.

[13 marks]

(b) A buck-boost converter shown in Figure Q3 operates at the switching frequency, f_S of 10 kHz from a 25 V DC source. It is supplying a 50 W load at a current value of 5 A. Given that the inductor of the circuit is 200 μH, determine

(i) The duty cycle, D.

[4 marks]

(ii) The minimum and maximum inductor currents (I_{Lmin} , I_{Lmax}).

[4 marks]

(iii) The average input current, I_{IN}.

[2 marks]

(iv) The average diode current, I_D.

[2 marks]

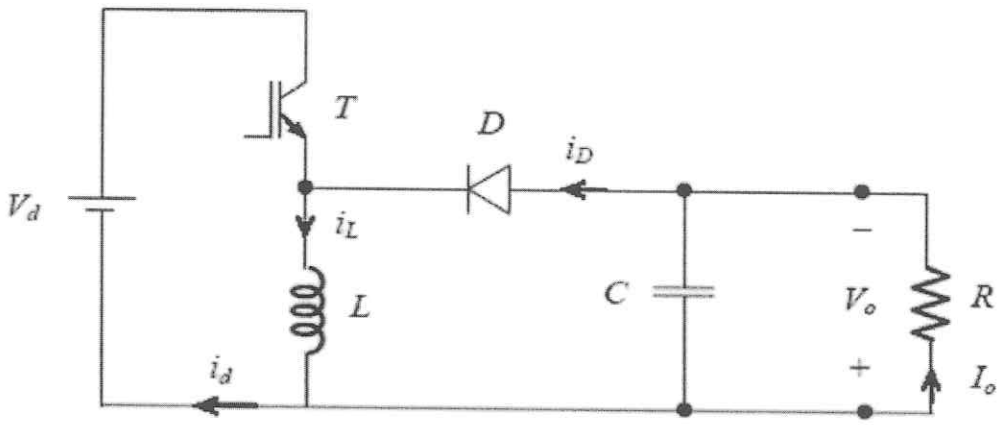

Figure Q3

Continued...

Question 4

a) A single-phase full-bridge PWM (pulse width modulation) inverter operates from a 200 V dc bus. The output is connected to a resistive load of 9 Ω.

(i) Determine the value of duty cycle needed to eliminate the third harmonic.

[4 marks]

(ii) Calculate the rms values of the total output voltage and the fundamental frequency output voltage at the duty cycle determined in part (i). (Considering the first, third, and fifth harmonic only)

[4 marks]

(iii) Calculate the total power delivered to the load considering the first, third, and fifth harmonics.

[8 marks]

(iv) Calculate the total harmonic distortion (THD) for output current.

[3 marks]

b) A series resonant inverter is shown in Figure Q4. Given output frequency (f_o) = 6.5 kHz, determine:

(i) Circuit turn-off time, t_{off}

[4 marks]

(ii) The maximum turn off time, t_q of the thyristor (T1).

[2 marks]

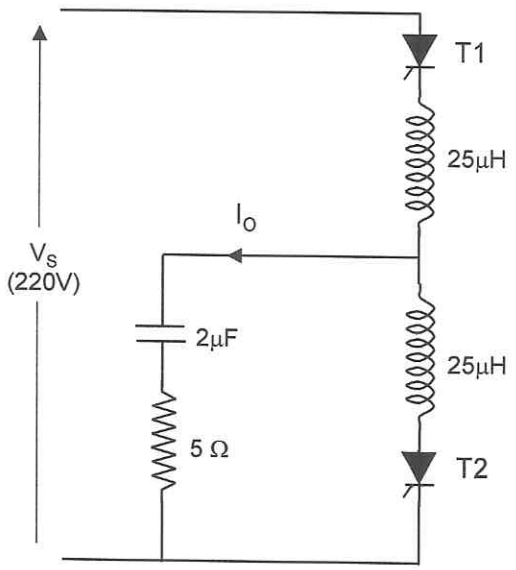

Figure Q4

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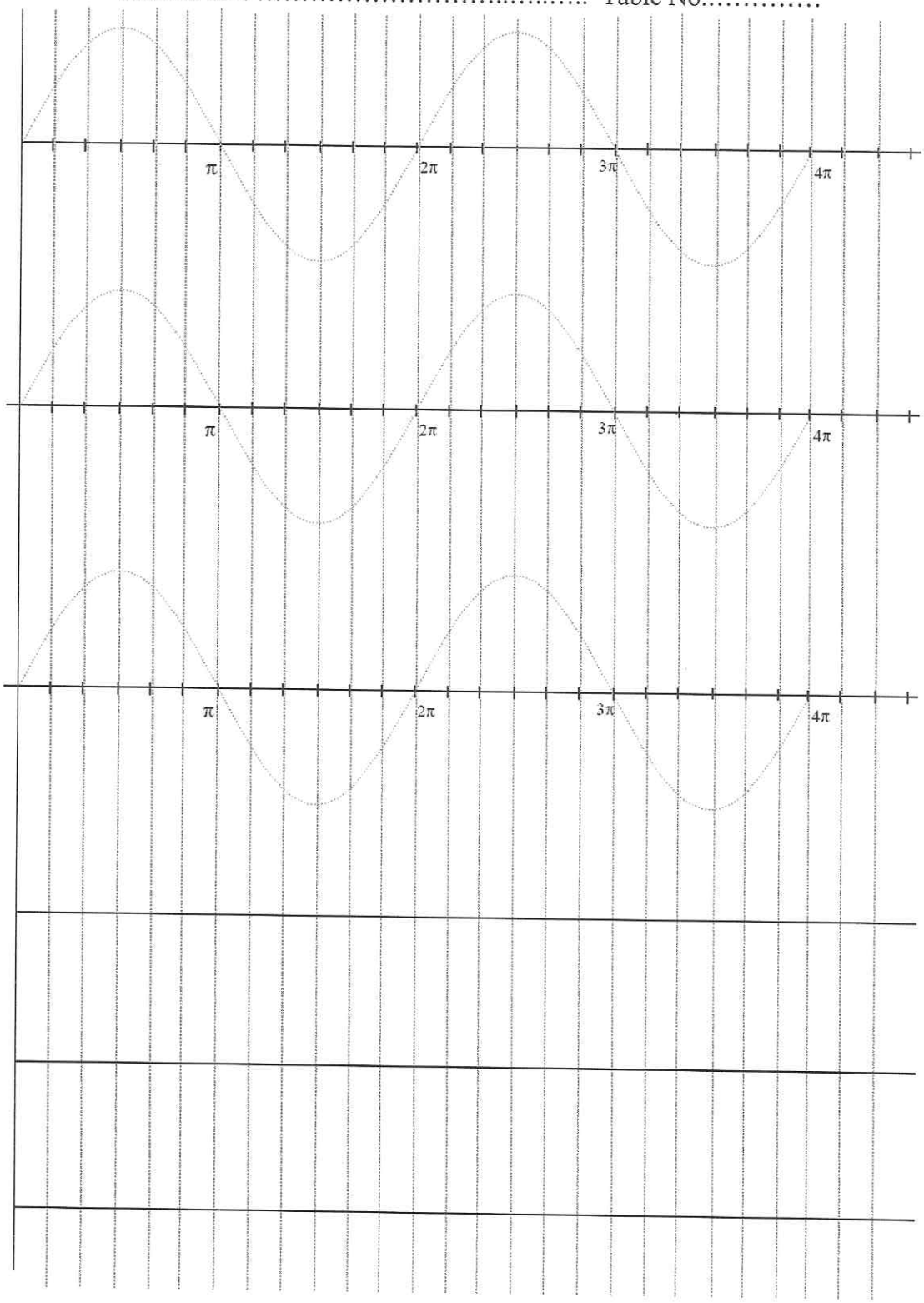
Appendix (For Question 2(a))

Student ID : …….…….. Table No.:……



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Examination Formula Sheet (Rev 2.0)

AC-DC Converters

Single Phase Uncontrolled Rectifiers (Half wave) , R load	Single Phase Uncontrolled Rectifiers (Half wave), RL Load
$V_{o,avg} = \frac{\sqrt{2}V_{S,rms}}{\pi}$, $V_{o,rms} == \frac{V_{S,rms}}{\sqrt{2}}$	$V_{o,avg} = \frac{\sqrt{2}V_{s,rms}}{2\pi}[1-\cos(\beta)]$ $V_{o,rms} = \frac{V_{s,rms}}{\sqrt{2\pi}}\sqrt{\beta - \frac{\sin 2\beta}{2}}$ $\beta \approx \pi + \theta$, $\theta = \tan^{-1}\left(\frac{\omega L}{R}\right)$
Single Phase Uncontrolled Rectifiers (Bridge Full wave)	Three Phase Uncontrolled Rectifiers (Half wave)
$V_{o,avg} = \frac{2\sqrt{2}V_{s,rms}}{\pi}$, $V_{o,rms} = V_{s,rms}$	$V_{o_avg} = \frac{3\sqrt{3}V_{l-n}}{\sqrt{2}\pi}$, $V_{0_rms} = 1.19V_{l-n}$
Three Phase Uncontrolled Rectifiers (Full wave)	Single Phase controlled Rectifiers (Half wave)
$V_{0_avg} = \frac{3\sqrt{2}V_{l-l}}{\pi}$, $V_{0_rms} = 0.963\ V_{l-l}$	$V_{0_avg} = \frac{V_{S,rms}}{\sqrt{2\pi}}(1+\cos\alpha)$ R Load $V_{0_avg} = \frac{V_{S,rms}}{\sqrt{2\pi}}(\cos\alpha + \cos\beta)$ RL Load
Single Phase controlled Rectifiers (Bridge Full wave)	Three Phase controlled Rectifiers (Half wave)
$V_{0_avg} = \frac{\sqrt{2}V_{S,rms}}{\pi}(1+\cos\alpha)$ R Load $V_{0_avg} = \frac{2\sqrt{2}V}{\pi}\cos\alpha$ RL Load	$V_{0_avg} = \frac{3\sqrt{2}}{2\pi}V_{AN}\left(1+\cos\left(\pi/6+\alpha\right)\right)$
Three Phase controlled Rectifiers (Full wave)	
$V_{0_avg} = \frac{3\sqrt{6}}{\pi}V_{AN}\left(\sin\left(\pi/6+\alpha\right)\right)$	

DC-DC Converters

Buck Converter (CCM)	Buck Converter (DCM)
$V_o = DV_d$ $I_{L\max} = V_o\left[\frac{1}{R} + \frac{(1-D)}{2Lf_s}\right]$ $I_{L\min} = V_o\left[\frac{1}{R} - \frac{(1-D)}{2Lf_s}\right]$	$\frac{V_o}{V_d} = \frac{D}{D+\Delta_1}$ $I_o = \frac{V_d T_s}{2L}D\Delta_1$

Continued…

DC-DC Converters (cont.)

Boost Converter (CCM)	Boost Converter (DCM)
$V_o = \frac{V_d}{1-D}$ $I_{L\max} = \frac{V_d}{(1-D)^2 R} + \frac{V_d D T_s}{2L}$ $I_{L\min} = \frac{V_d}{(1-D)^2 R} - \frac{V_d D T_s}{2L}$	$\frac{V_o}{V_d} = \frac{\Delta_1 + D}{\Delta_1}$ $I_o = \frac{V_d T_s}{2L} D\Delta_1$
Buck-Boost Converter (CCM)	**Buck-Boost Converter (DCM)**
$V_o = \frac{V_d D}{1-D}$ $I_{L\max} = \frac{V_d D}{R(1-D)^2} + \frac{V_d D T_s}{2L}$ $I_{L\min} = \frac{V_d D}{R(1-D)^2} - \frac{V_d D T_s}{2L}$	$\frac{V_o}{V_d} = \frac{D}{\Delta_1}$ $I_o = \frac{V_d D}{2 f_s L}(D + \Delta_1) - \frac{D I_o}{\Delta_1}$
Flyback Converter (CCM)	**Flyback Converter (DCM)**
$\frac{V_o}{V_d} = \frac{N_2}{N_1}\frac{D}{1-D}$ $I_{L\max} = \frac{V_d D}{R(1-D)^2}\left[\frac{N_2}{N_1}\right]^2 + \frac{V_d D T_s}{2L_m}$ $I_{L\min} = \frac{V_d D}{R(1-D)^2}\left[\frac{N_2}{N_1}\right]^2 - \frac{V_d D T_s}{2L_m}$	$\frac{V_o}{V_d} = D\sqrt{\frac{R}{2 f_s L_m}}$ $I_o = \frac{V_o}{R}$

DC- AC Converters

Single-Phase Half-bridge Inverter with RL load	Resonant Converters
$v_o(\omega t) = \sum_{n=1,3,5,\ldots}^{\infty} \frac{2V_s}{n\pi}\sin(n\omega t)$ Single-phase full-bridge PWM inverter (Square Wave) $v_o(\omega t) = \sum_{n=1,3,5,\ldots}^{\infty} \frac{4V_s}{n\pi}\sin(n\omega t)$ Single-phase full-bridge PWM inverter (Quasi Square Wave) $v(\omega t) = \sum_{n=1,3,5\ldots}^{\infty} \frac{4V_s}{n\pi}\sin\frac{nD\pi}{2}\cos n(\omega t - \frac{D\pi}{2})$	$\omega_r = \sqrt{\frac{1}{LC} - \frac{R^2}{4L^2}}$

End of Paper